CLAIMS

What is claimed is:

1. An apparatus for providing non-contact thermal measurements at high spatial and thermal resolutions, comprising:

an illumination source;

means for generating a signal in response to registration of the magnitude of light received from said illumination source that is reflected from the surface of an object; and

means for generating a bandwidth-limited AC-component of the signal from said illumination detector while said object is subjected to modulated thermal excitation.

2. An apparatus for providing non-contact thermal measurements at high spatial and thermal resolutions, comprising:

an illumination source;

an array of individual illumination detectors;

said illumination detectors configured to generate signals in response to registration of the magnitude of light received from said illumination source that is reflected from the surface of an object; and

a signal processor;

said signal processor configured to filter one or more direct current components from said signal while said object is subjected to modulated thermal excitation to discern a small thermoreflectance signal from noise.

3. An apparatus as recited in claim 1, wherein said means for generating a signal in response to registration of the magnitude of light received from said illumination source that is reflected from the surface of an object comprises:

an array of individual illumination detectors.

4. An apparatus as recited in claim 3, wherein:

said array of illumination detectors is adapted to generate information on the intensity of light received by each of said individual illumination detectors in the array.

5. An apparatus as recited in claim 1 or 2, further comprising:

a display;

said display adapted for displaying a bandwidth-limited AC-component of the signal.

6. An apparatus as recited in claim 1 or 2, further comprising:

means for receiving a bandwidth-limited AC-component of the signal and computing a thermal measurement based on a change in registered surface reflectance.

7. An apparatus as recited in claim 6:

wherein said object has a known thermoreflectance constant; and

wherein said change in registered surface reflectance is in response to a change in the thermoreflectance coefficient of the surface material of said object resulting from a temperature change associated with said thermal excitation.

8. An apparatus as recited in claim 1 or 2, further comprising:

means for generating a superresolution image from a combination of thermal images having a lower spatial resolution.

9. An apparatus as recited in claim 8, wherein said means for generating a superresolution image comprises:

a computer; and

programming associated with said computer for,

receiving a plurality of thermal images having a first image resolution, and

combining said thermal images having said first resolution by interpolating pixel values into a thermal image having a higher second resolution.

10. An apparatus as recited in claim 1 or 2, wherein said illumination source comprises a laser light source.

11. An apparatus as recited in claim 10, wherein said laser light source operates at wavelength ranging from approximately 500 nm to approximately 800 nm.

12. An apparatus as recited in claim 10, wherein said laser light source has a wavelength of approximately 655 nm.

13. An apparatus as recited in claim 10, wherein said laser light source has an output power ranging from approximately 1 mW to approximately 100 mW.

14. An apparatus as recited in claim 10, wherein said laser light source has an output power of approximately 5 mW.

15. An apparatus as recited in claim 1 or 2, further comprising:

an x-y translation stage;

said translation stage configured to provide motion to said illumination source and said illumination detector in relation to the surface of said object;

wherein a thermal image may be constructed from data collected during scanning of the surface of said object.

16. An apparatus as recited in claim 15:

wherein said x-y translation stage comprises a piezoelectric translation stage;

wherein said translation stage provides movement resolution that is approximately equal to or higher than the desired spatial resolution at which the object is being measured.

17. An apparatus as recited in claim 1 or 2:

wherein said illumination source is configured to generate a beam spot size that approximates, or is less than, the desired spatial resolution of thermal measurement.

18. An apparatus as recited in claim 17, further comprising:

an inverse-filter which is applied to remove image blurring caused by an excessively large illumination spot size.

19. An apparatus as recited in claim 1 or 2, wherein said illumination detector comprises a photodiode.

20. An apparatus as recited in claim 2 or 3, wherein said array of illumination detectors comprises an array of photodetectors ranging in size from approximately 16 x 16 array to approximately 64 x 64.

21. An apparatus as recited in claim 2 or 3, wherein said array of illumination detector comprises an array of photodetectors ranging in size from approximately 2 x 2 to approximately 256 x 256.

22. An apparatus as recited in claim 1 or 2, wherein the frequency range of said modulated thermal excitation to which said object is subjected ranges from

approximately 0.1 Hz to approximately 100 kHz.

23. An apparatus as recited in claim 1, wherein said means for generating a bandwidth-limited AC-component of the signal from said illumination detector while said object is subjected to modulated thermal excitation comprises:

a signal processor;

said signal processor configured to filter one or more direct current components from said signal to discern a small thermoreflectance signal from noise.

24. An apparatus as recited in claim 2 or 23, wherein said signal processor is selected from the group of narrow band filters consisting essentially of a lock-in amplifier, differential boxcar averaging circuit, and FFT analyzer.

25. An apparatus as recited in claim 2 or 23, wherein said signal processor is configured to filter out components of the signal other than a single harmonic of the registered illumination level.

26. A method as recited in claim 25:

wherein said single harmonic that is at, or associated with, the frequency of modulation to which said object is subjected.

27. An apparatus as recited in claim 2 or 23, wherein said signal processor is configured to pass a band of frequencies that is less than approximately 10 Hz.

28. An apparatus as recited in claim 2 or 23, wherein signal processor has a passband having a maximum width of approximately 1 Hz.

29. An apparatus as recited in claim 2 or 23, wherein said signal processor is configured to pass a band of frequencies that is limited to approximately 0.1 Hz.

30. An apparatus as recited in claim 1 or 2, further comprising:

an imaging device adapted to receive a portion of the reflected illumination for aligning position of the illumination source in relation to the object.

31. An apparatus as recited in claim 30, further comprising:

a splitter configured to direct portions of said reflected illumination to said imaging device.

32. An apparatus for thermal imaging of an object and providing a superresolution image having a resolution exceeding the resolution of the imaging optics, comprising:

means for obtaining a plurality of images shifted by $1/N$ pixel lengths, where N

is the desired increase in resolution, in the positive and negative of two planar dimensions; and

means for combining said plurality of images into one image with high resolution.

33. An apparatus as recited in claim 32, wherein said means for obtaining said plurality of images shifted by $1/N$ pixel lengths comprises a translation stage capable of sub pixel sized translation movements.

34. An apparatus as recited in claim 32, wherein said means for combining said plurality of images comprises:

a computer; and

programming associated with said computer for performing pixel interpolation in combining said plurality of images into an image having a higher resolution.

35. An apparatus for thermal imaging of an object and providing a superresolution image having a resolution exceeding the resolution of the imaging optics, comprising:

a translation stage capable of sub pixel sized translation movements and obtaining a plurality of images shifted by $1/N$ pixel lengths, where N is the desired increase in resolution, in the positive and negative of two planar dimensions; and

means for combining said plurality of images into one image with high resolution.

36. An apparatus as recited in claim 35, wherein said means for combining said plurality of images comprises:

a computer; and

programming associated with said computer for performing pixel interpolation in combining said plurality of images into an image having a higher resolution.

37. An apparatus for thermal imaging of an object and providing a superresolution image having a resolution exceeding the resolution of the imaging optics, comprising:

means for obtaining a plurality of images shifted by $1/N$ pixel lengths, where N is the desired increase in resolution, in the positive and negative of two planar dimensions;

a computer; and

programming associated with said computer for performing pixel interpolation in combining said plurality of images into an image having a higher resolution.

38. An apparatus as recited in claim 37, wherein said means for obtaining said plurality of images shifted by $1/N$ pixel lengths comprises a translation stage capable of sub pixel sized translation movements.

39. An apparatus for thermal imaging of an object and providing a superresolution image having a resolution exceeding the resolution of the imaging optics, comprising:

a translation stage capable of sub pixel sized translation movements obtaining a plurality of images shifted by $1/N$ pixel lengths, where N is the desired increase in resolution, in the positive and negative of two planar dimensions;

a computer; and

programming associated with said computer for performing pixel interpolation in combining said plurality of images into an image having a higher resolution.

40. A method for providing high resolution thermal imaging of an object being subjected to thermal modulation, comprising:

illuminating an area on the surface of an object for which thermal information is desired;

detecting illumination reflected from said area; and

generating an AC-coupled bandwidth-limited signal in response to detected illumination.

41. A method as recited in claim 40:

wherein said AC-coupled signal has a bandwidth with a center at, or associated with, the frequency of modulation to which said object is subjected.

42. A method as recited in claim 40, further comprising:

resolving the AC-coupled signal into an image.

43. A method for providing high resolution thermal imaging of an object being subjected to thermal modulation, comprising:

illuminating an area on the surface of an object for which thermal information is desired;

detecting illumination reflected from said area;

generating an AC-coupled bandwidth-limited signal in response to detected illumination; and

resolving the AC-coupled signal into an image.

44. A method as recited in claim 43:

wherein said AC-coupled signal has a bandwidth with a center at, or associated with, the frequency of modulation to which said object is subjected.

45. A method for generating superresolution thermal images from low resolution thermal images, comprising:

obtaining multiple thermoreflective images of a first spatial resolution by micro-scanning; and

combining said micro-scanned thermoreflective images of a first resolution by

interpolating pixels to obtain an image of a second resolution which is higher than said first spatial resolution.

46. A method as recited in claim 45:

wherein sufficient sub pixel offsets are represented within said multiple thermoreflective images of said first spatial resolution so that the pixel interpolation can yield the desired level of resolution enhancement.

47. A method as recited in claim 44, wherein said obtaining of multiple thermoreflective images is performed by acquiring thermoreflective measurements at a series of sub pixel offsets during micro-scanning.

48. A method for converting a plurality of low-spatial-resolution thermal images of a device into a superresolution thermal image having increased spatial resolution, comprising:

obtaining a plurality of images shifted by $1/N$ pixel lengths, where N is the desired increase in resolution, in the positive and negative directions of two planar dimensions; and

interpolating the pixels within said plurality of images into one image with high resolution.